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Dark Energy Survey Supernovae

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High Energy Physics Division

Leadership Computing Facility

Argonne National Laboratory

Key Contributors

Argonne DES group members: Kyler **Kuehn**, Steve **Kuhlmann** (group leader), Hal **Spinka**, Rich **Talaga**

Other DES members: Rick **Kessler** (U. Chicago), John **Marriner** (Fermilab)

Argonne mechanical group: Vic **Guarino**, Tom **Kasprzyk**, Frank **Skrzecz**, Allen **Zhao**

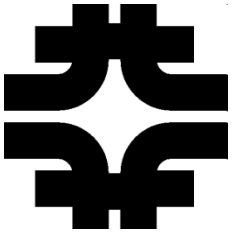
More: Eve **Kovacs**, John **Cunningham** (Loyola Chicago), **Ian Crane** (U. Illinois), Tara **Hufford** (Loyola Chicago)

CAS Seminar
Johns Hopkins University
July 1, 2010

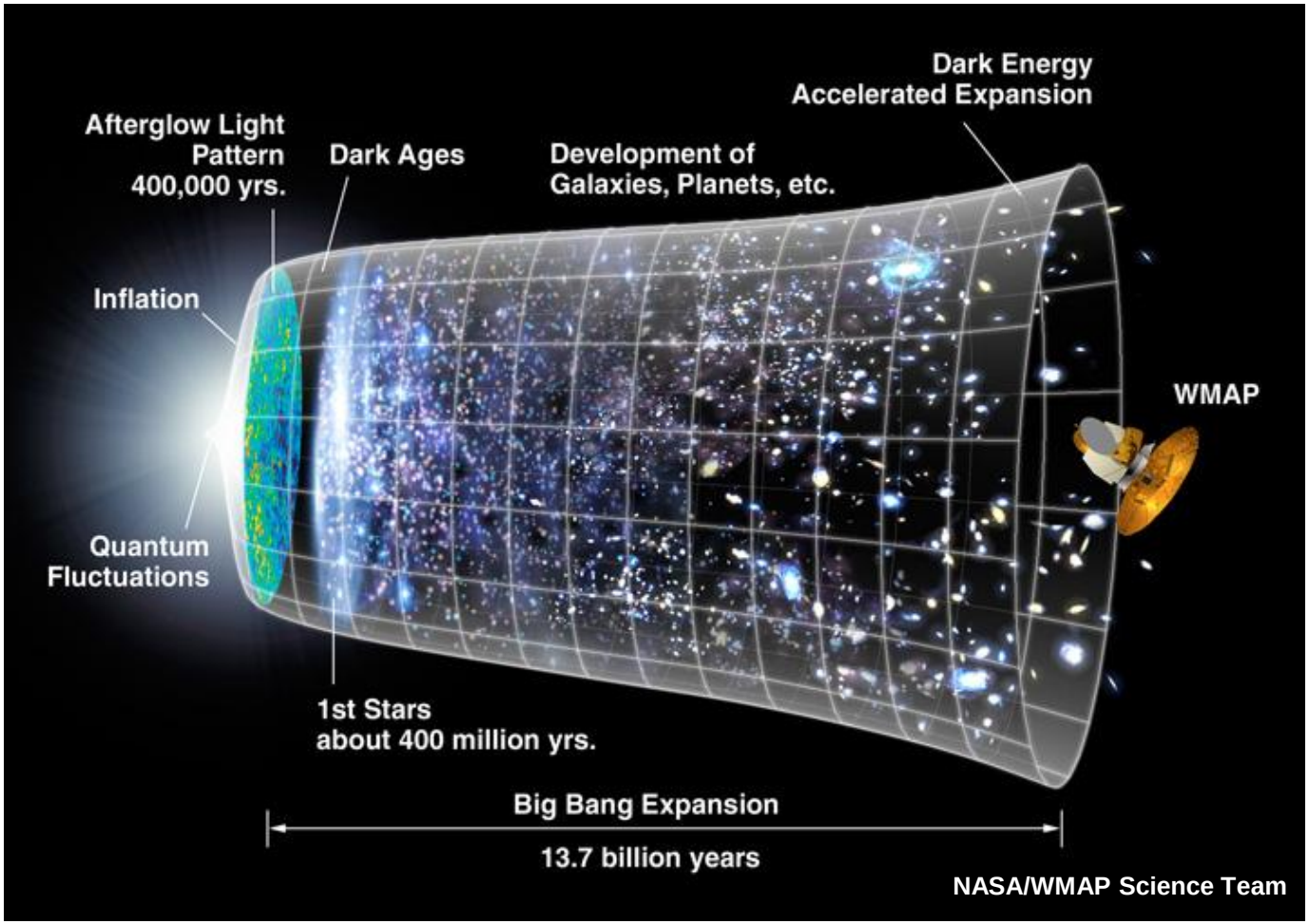
Outline

- Dark Energy Survey (DES) Intro
- Dark Energy Camera (DECam)
- PreCam (e.g., “mini-DECam”)
- Studies of DECam charged coupled devices
- Studies of the DES Supernova Observing Strategy
- Summary & conclusions

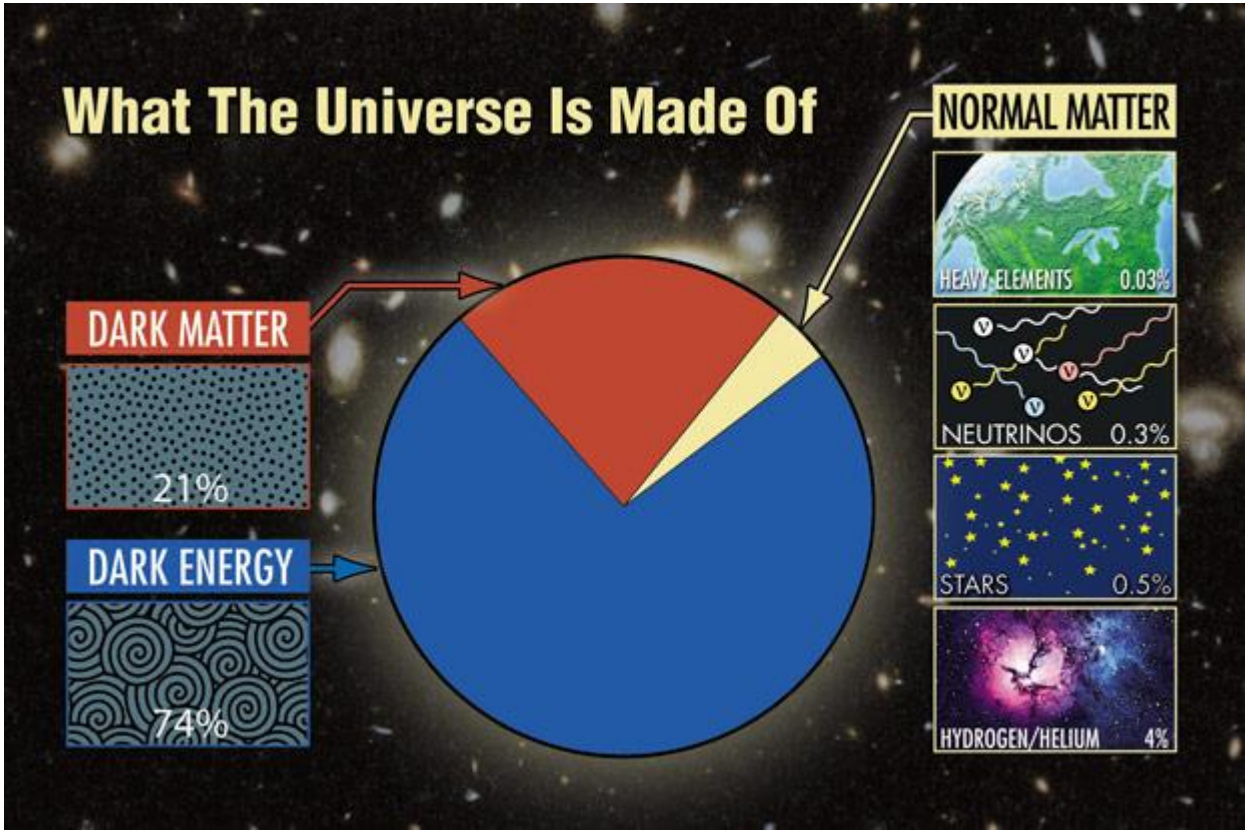
DARK ENERGY
SURVEY



Expansion of the Universe



Have A Slice Of Universe Pie



Courtesy: http://hetdex.org

Fundamental Motivation

DARK ENERGY SURVEY

Discovering the evolution & ultimate fate of the Universe and determining what constitutes 95% of the Universe!

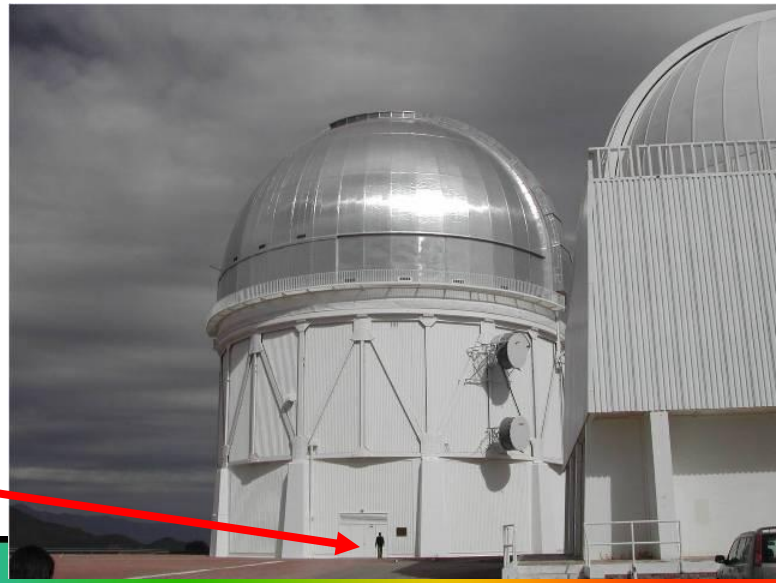
Dark Energy Survey (DES)

DES will survey 5000 square degree of sky and provide new 500Mpixel CCD camera (DECam) for Blanco 4m telescope at the Cerro Tololo Inter-American Observatory (CTIO), Chile, in exchange for 525 survey nights over 5 years starting in 2011.

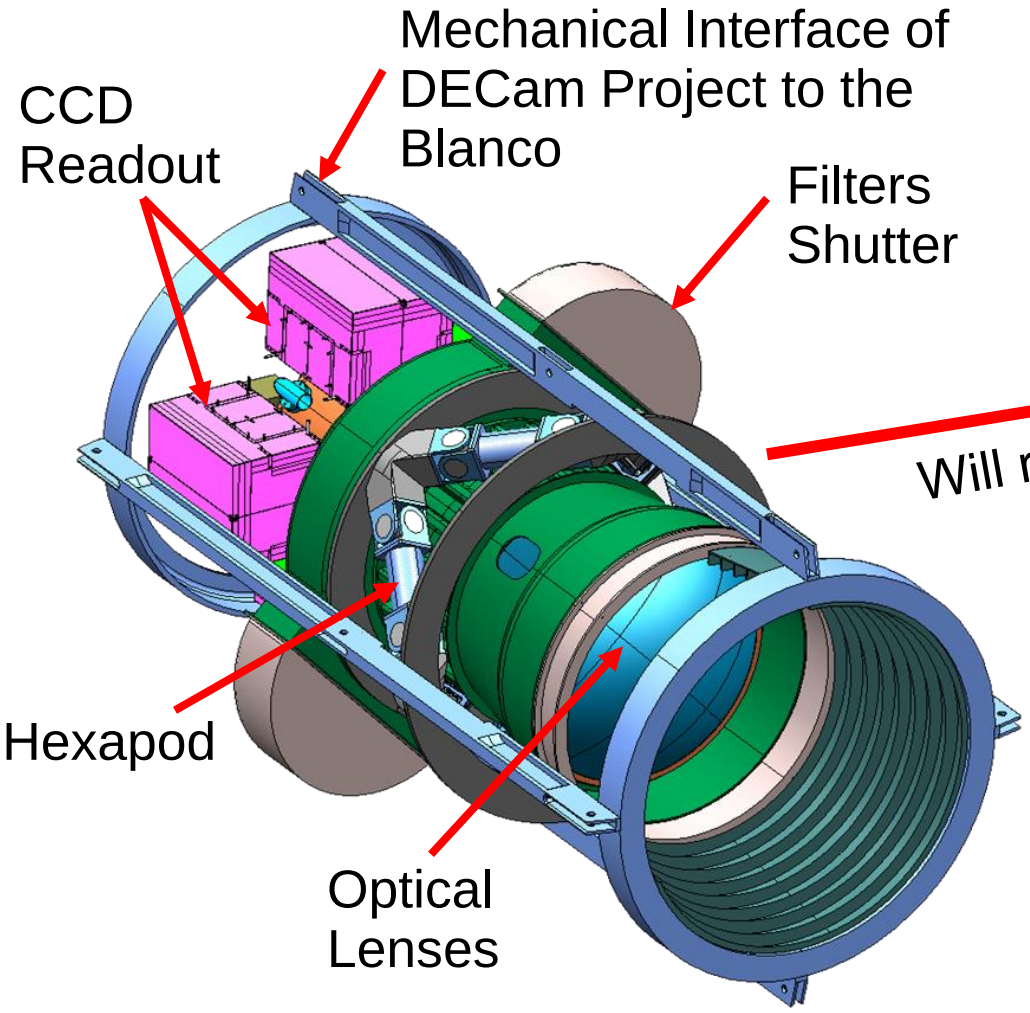
DE investigation via 4 independent probes:
1) Galaxy angular clustering
2) Weak gravitational lensing
3) Baryon acoustic oscillations
4) SN Ia distances

DES is expected to observe ~10^8 galaxies & will obtain redshifts for the South Pole Telescope survey.

JPB



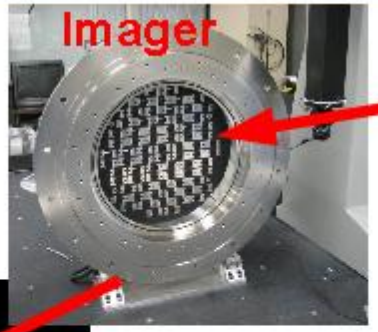
Dark Energy Camera (DECam)

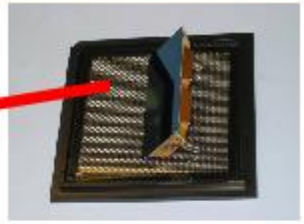


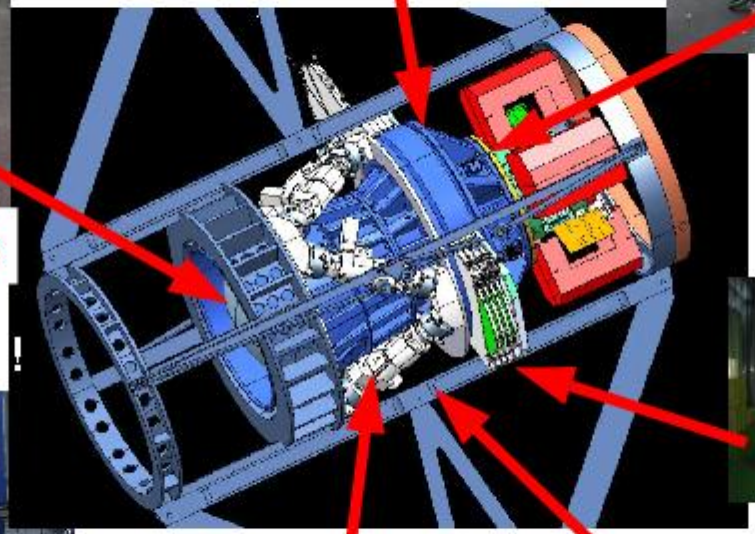
Will replace

Dark Energy Camera (DECam)

1st of 5 lenses







Full-Scale Telescope Simulator

Mosaic Image Using Prototype DECam Imager
(currently using poor-grade CCDs)

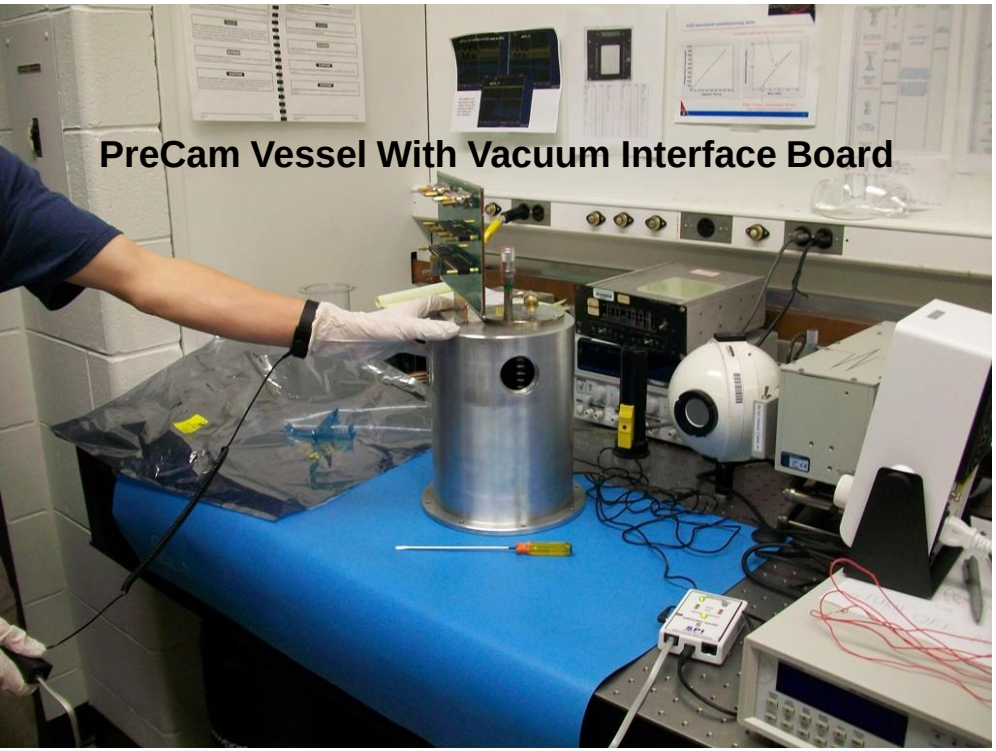
f/8 Handling System

- Used to install and remove the f/8 secondary mirror from the front of DECam
- Assembled and tested at ANL
- Shipment to FNAL complete
- First piece of DECam to go through acceptance testing
- Will go through official hand-off and shipping process to CTIO this summer (winter)

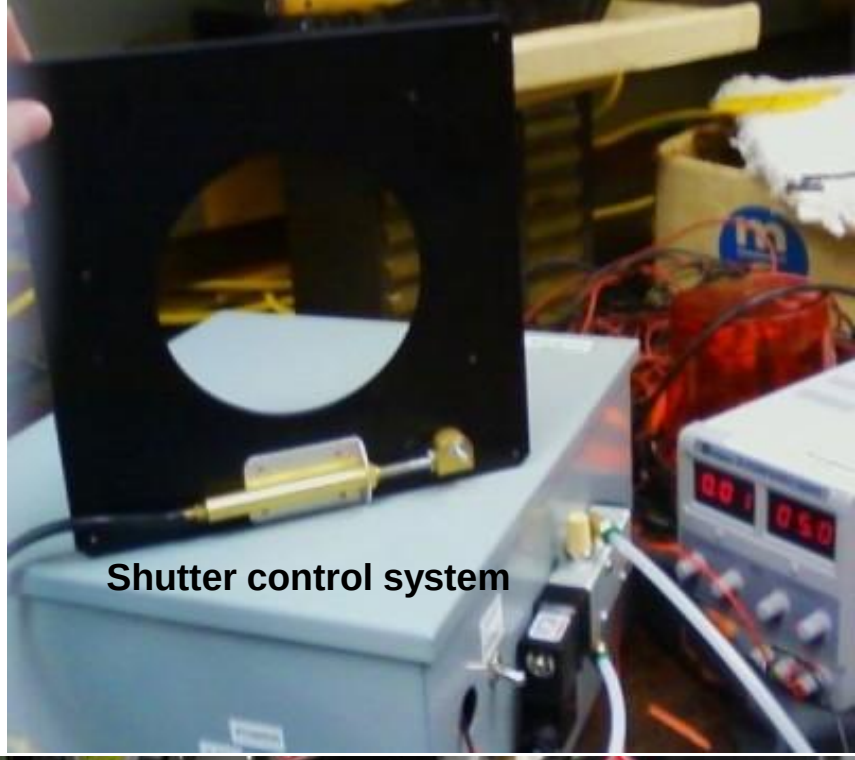
PreCam: a "mini-DECam," pre-DES Survey

- Science motivation for pre-survey observations with DECam hardware
  - 0.01 calibrated stars/image: ~1000 with SNR>50
  - reach 2% photometry requirement faster (1 yr vs 2yr?)
  - better chance to reach 1% photometry goal
  - dark energy EOS parameter uncertainty due to photometry is 0.06 with 2% photometry (0.03 with 1%)
- Test-bed for DECam hardware, software, and observing strategies
- PreCam components being tested at ANL
  - pressure vessel & turbo pump: can obtain pressures $<10^{-5}$ mbar
  - shutter control system: controls image exposure time
  - temperature control system: can regulate the CCD & vessel to 0.25K
  - dewer mounting plate
  - electronic readout crate
  - DAQ software
  - extremely red-sensitive (DECam) CCDs

Actual PreCam Hardware

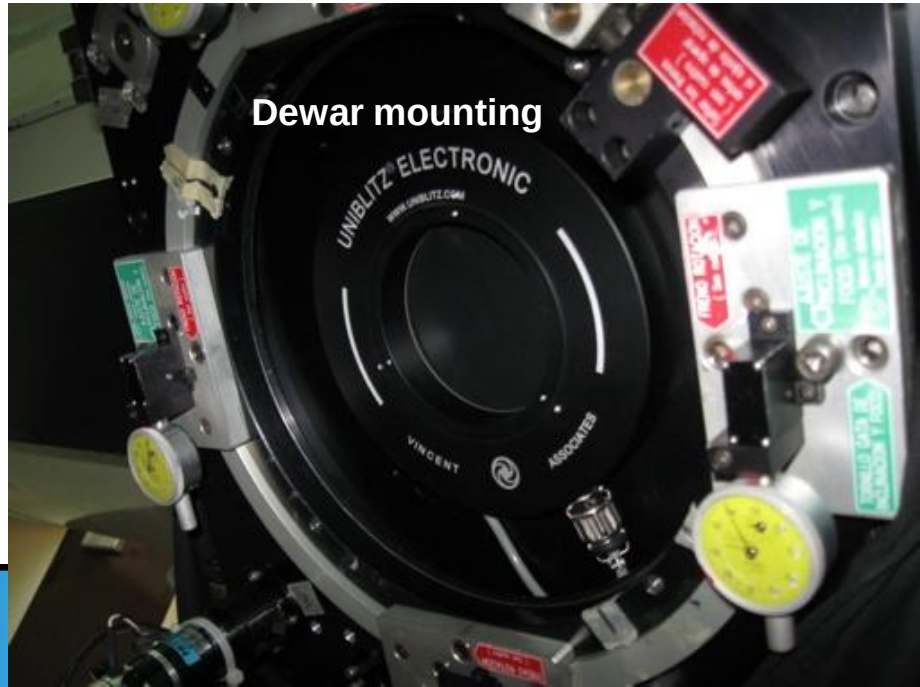


PreCam Vessel With Vacuum Interface Board



Shutter control system

Thermal transfer block, heaters, RTDs

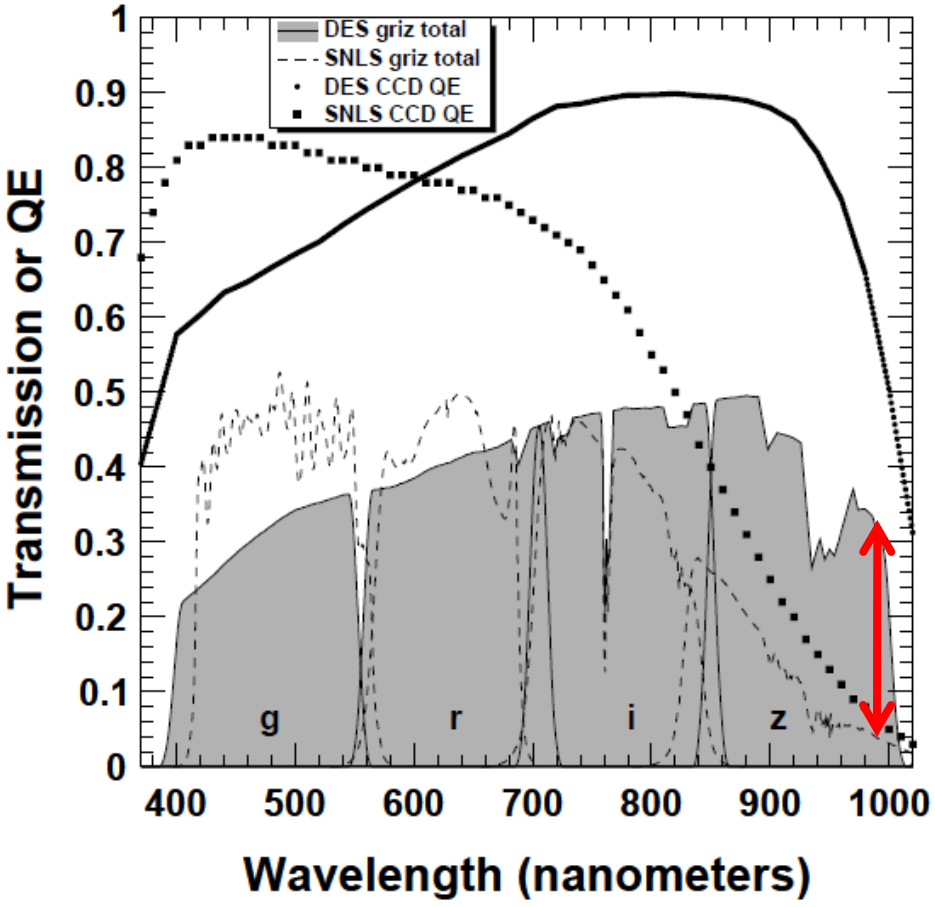


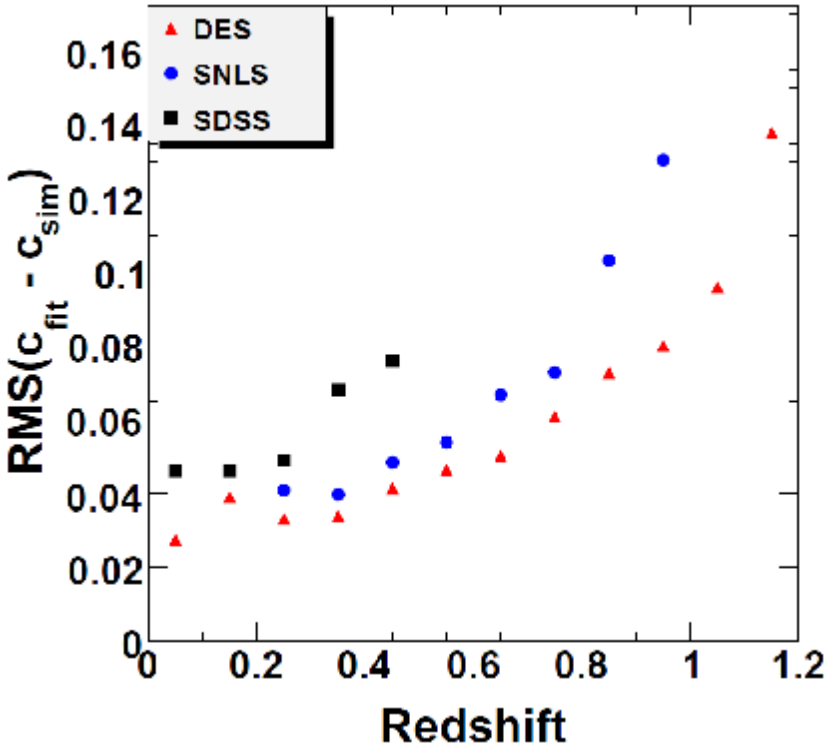
Dewar mounting

Arg

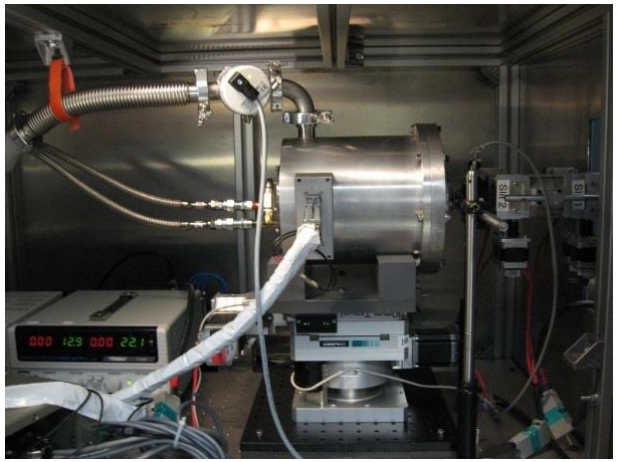
DES Compared to SNLS and SDSS

SNLS data from Regnault et al 2009, A&A., 506, 999

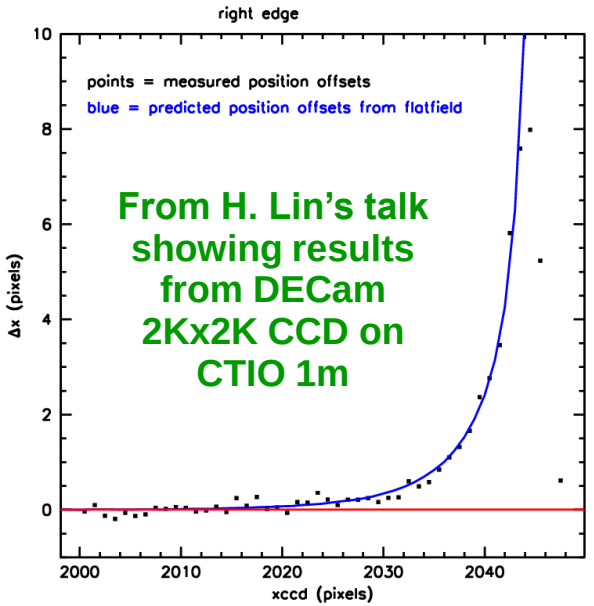




DECam Charged Coupled Device Studies: X-ray irradiation studies in APS X-ray Lab



Paper Submitted



From H. Lin's talk showing results from DECam 2Kx2K CCD on CTIO 1m

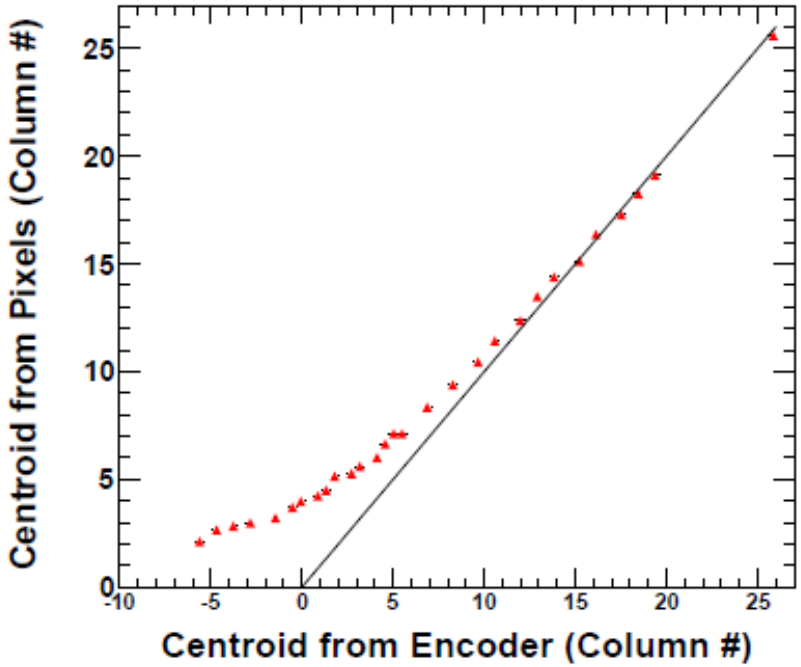
Experimental Astronomy manuscript No.
(will be inserted by the editor)

Narrow-Beam X-Ray Tests of CCD Edge Response

S. Kuhlmann · H. Spinka · J. P. Bernstein · K. A. Beyer · L. M. Gades · T. E. Kasprzyk · A. Miceli · R. A. Spence · R. Talaga

Received: date / Accepted: date

Abstract The physical boundaries of a fully-depleted CCD can lead to distorted field lines and non-uniform response. We study this response with a beam of x-rays constrained to a width of less than one pixel (15 μm), and a system to map the CCD response as a function of transverse position.



ANL SN Refs

Dark Energy Survey Supernovae: Simulations and Survey Strategy

Cosmology, Proceedings of the 43rd Rencontres de Moriond", Eds. J. Dumarchez, Y. Giraud-Heraud, J. Tran Thanh Van, pp.71-74, 2009, The Gioi Publishers, Vietnam

http://arxiv.org/abs/0906.2955

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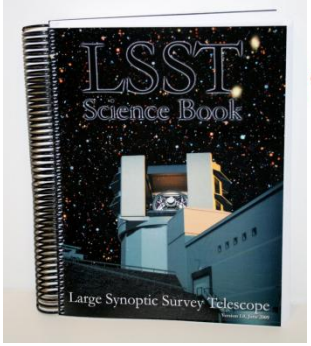
For the Dark Energy Survey Collaboration



DARK ENERGY SURVEY

LSST Science Collaborations and LSST Project 2009, LSST Science Book, Version 2.0, arXiv:0912.0201, http://www.lsst.org/lsst/scibook

SNANA: A PUBLIC SOFTWARE PACKAGE FOR SUPERNOVA ANALYSIS

Richard Kessler,[1,2] Joseph P. Bernstein,[3] David Cinabro,[5] Benjamin Dilday,[4] Joshua A. Frieman,[2,1,6] Saurabh Jha,[4] Stephen Kuhlmann,[3] Gajus Miknaitis,[7,6] Masao Sako,[8] Matt Taylor,[5] Jake VanderPlas[9]

Publications of the Astronomical Society of the Pacific, Volume 121, issue 883, pp.1028-1035 DOI: 10.1086/605984

PHOTOMETRIC ESTIMATES OF REDSHIFTS AND DISTANCE MODULI FOR TYPE IA SUPERNOVAE

Richard Kessler,[1,2] David Cinabro,[3] Bruce Bassett,[11,12] Benjamin Dilday,[4] Joshua A. Frieman,[1,2,5] Peter M. Garnavich,[6] Saurabh Jha,[4] John Marriner,[5] Robert C. Nichol,[7] Masao Sako,[9] Mathew Smith,[11] Joseph P. Bernstein,[8] Dmitry Bizyaev,[13] Ariel Goobar,[14,15] Stephen Kuhlmann,[8] Donald P. Schneider,[10] Maximilian Stritzinger[16,17]

Accepted by ApJ

http://arxiv.org/abs/1001.0738

SUPERNOVA PHOTOMETRIC CLASSIFICATION CHALLENGE

Richard Kessler,[1,2] Alex Conley,[3] Saurabh Jha,[4] Stephen Kuhlmann[5]

Challenge Released on Jan 29, 2010. Last update: April 29, 2010

http://arxiv.org/abs/1001.5210

Supernovae Simulations and Strategies: Application to the Dark Energy Survey (Draft: April 19, 2010)

J. P. Bernstein[1], R. Kessler[2,3], S. Kuhlmann[1], R. Reis[4], I. Crane[1,5], D. A. Finley[4], J. A. Frieman[2,3,4], T. Hufford[1], A. G. Kim[6], J. Marriner[4], P. Mukherjee[7], R. C. Nichol[8], P. Nugent[6], D. R. Parkinson[7], M. Sako[9], H. Spinka[1]. . .

SNANA: SuperNova ANAlysis package for DES

DARK ENERGY SURVEY

R. Kessler (U. Chicago), J. P. Bernstein, S. Kuhlmann, & H. Spinka (ANL)

- Also used by SDSS & LSST
- Software suite for simulating and fitting SN light curves
- Motivation was a more accurate and complete study of DES-SN capabilities including DES CCD and filter characteristics, CTIO sky fluctuations using Essence data inputs, dust extinction effects, etc.
- Uses various models (e.g., MLCS2k2, SALT-II, stretch, etc.)
- Models and fits both Ia and non-Ia SNe
- Public URL: http://www.sdss.org/supernova/SNANA.html

SNANA

Welcome to the SuperNova ANAlysis software homepage

Install Guide | SNANA Manual | Overview Paper | Legal Notice

SNANA Download | Mailing List | Contact Form

SNANA contains a light curve fitter and simulation that can be applied to any supernova (SN) model and to any data set. This website provides installation instructions, a user manual, and a software package download area.

SNANA Downloads

Current Software Release

Downloads	Version	Description
SNANA.tar.gz	v8_08	Source code (few MB)
SNDATA_ROOT.tar.gz	2009-05-14	Data & input files, model parameters, etc. (> 1 GB)

SNANA Software Archive (directory listing only)

Back to the SNANA Homepage

SNANA Description

- Computes rest-frame model magnitudes using various models
- Applies random color/luminosity fluctuations
- Includes host galaxy dust extinction
- Applies K-corrections
- Offers a choice of cosmologies
- Applies Milky Way dust extinction via Schlegel maps*
- Uses survey zero-points to convert magnitudes to flux
- CCD gain, noise, and sky noise added
- Fitter included for resulting light curves

* Schlegel, Finkbeiner, Davis 1998, ApJ, 500, 525

DES Supernovae

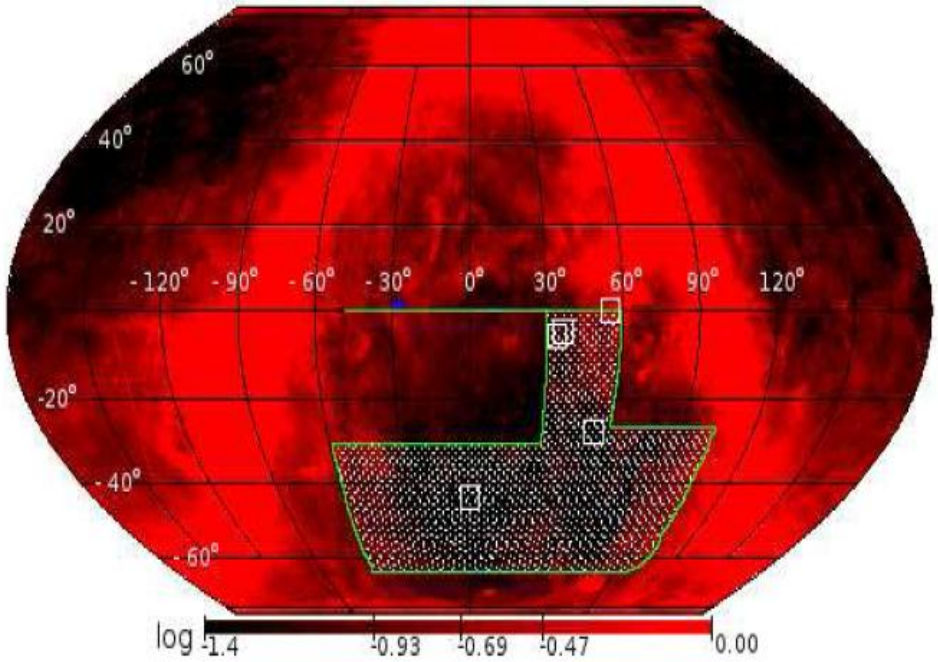
- DES time allocation fixes total supernovae (SNe) exposure time
  - 1260 hr planned (73% non-photometric) over 5-year survey
  - maximal use of non-photometric time (~920 hr) planned
- Considered time per field & number of fields:
  - ultra-deep strategy (3 square degrees = 1 DES field)
  - deep strategy (9 square deg.)*
  - shallow but wide strategy (27 square deg.)
  - hybrid strategy, e.g., 2 deep + 3 wide (15 square deg.)
- Hybrid *griz* strategy is the current favorite (more later)

* Highlighted in DES DOE proposal

Currently Favored DES-SN Fields

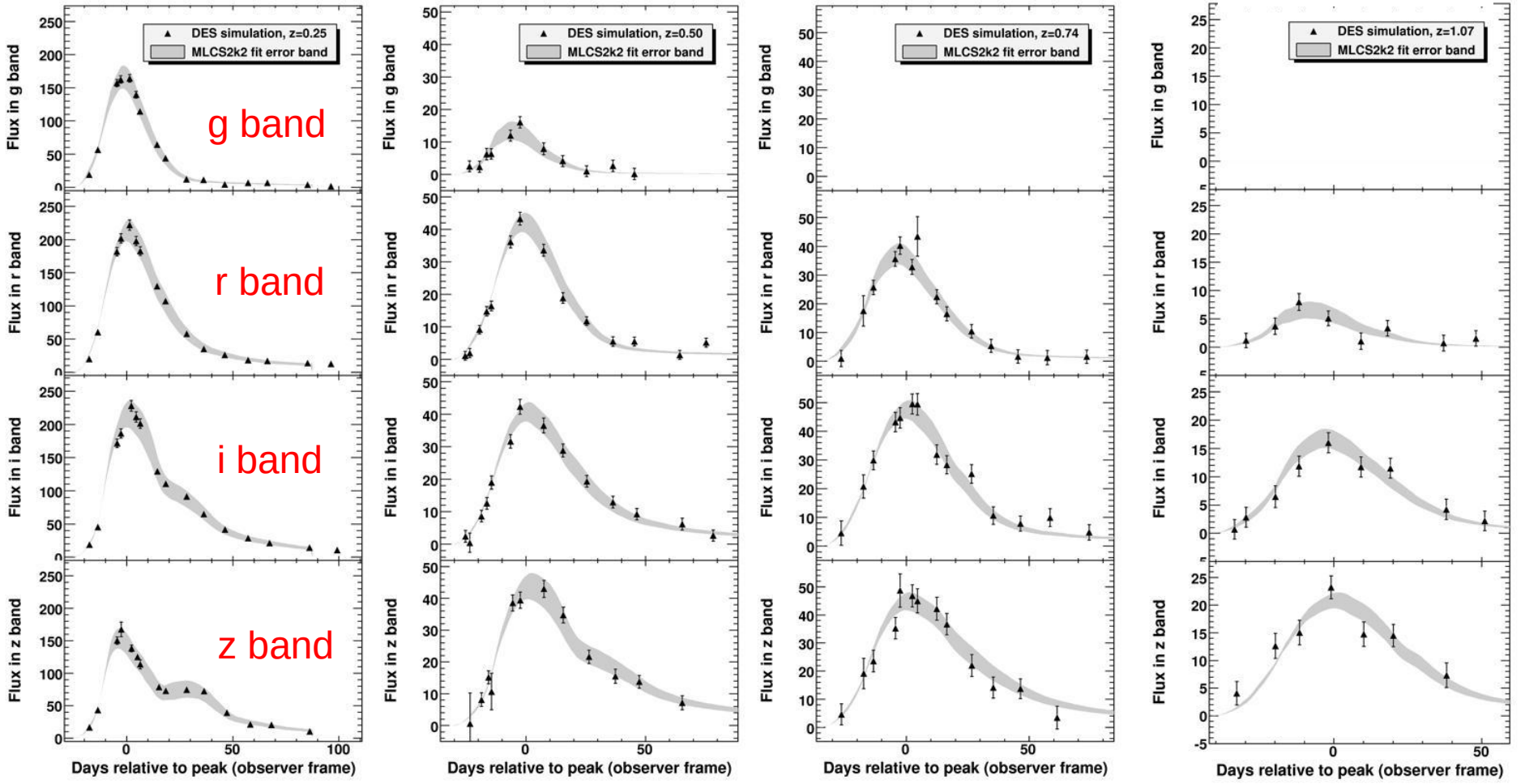
- Chosen to maximize:
  - visibility from DES site
  - past observation history
  - visibility from, e.g, Hawaii

Field (3 deg^2 area)	Pointing RA&Dec (deg., J2000)
Chandra Deep Field S.	52.5°, –27.5°
Sloan Stripe 82	55.0°, 0.0°
SNLS D1/Virmos VLT	36.75°, –4.5°
XMM-LSS	34.5°, –5.5°
ELAIS S1	0.5°, –43.0°



From a study by Peter Nugent

Example DES Simulated SN Ia Light Curves



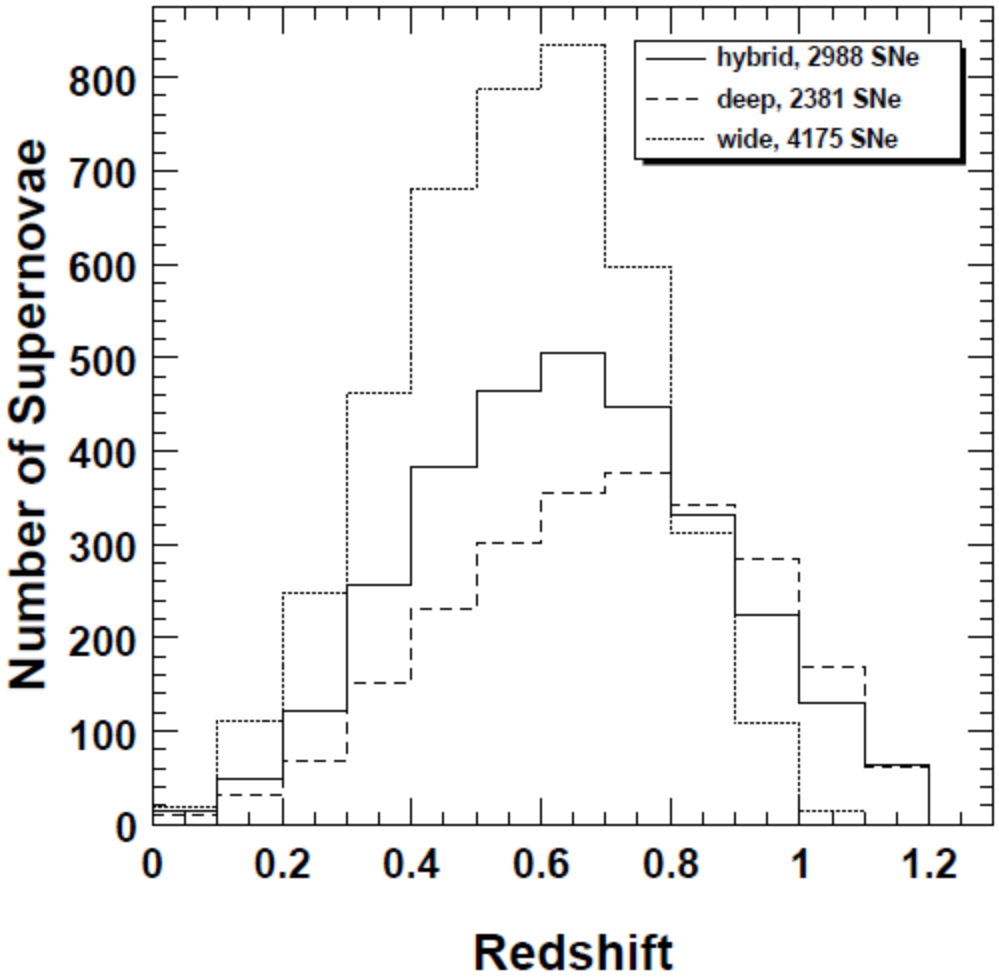
Selection cuts for DES supernovae
1. At least 5 total epochs above a very small, but non-zero, signal-to-noise threshold
2. At least one epoch before and at least one 10 days after the B-band peak
3. At least one filter measurement with a signal-to-noise above 10
4. At least two additional filter measurements with a signal-to-noise above 5

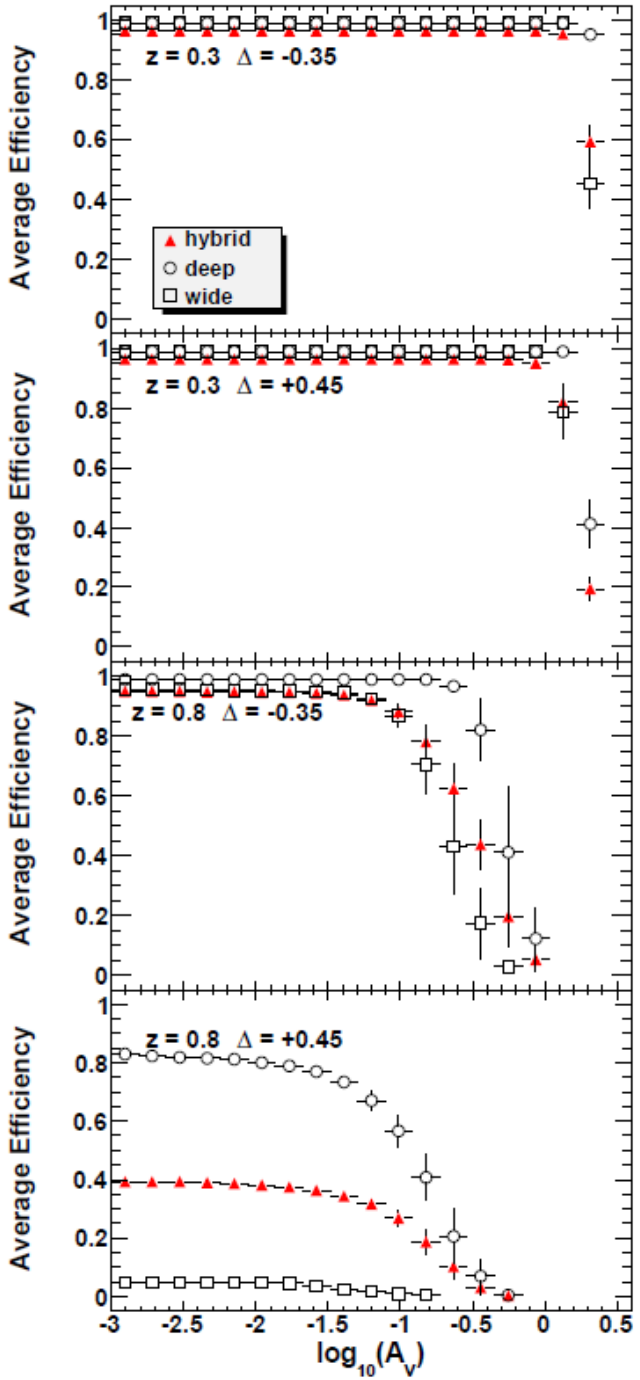
g band: 400 – 550 nm i band: 700 – 850 nm
r band: 560 – 710 nm z band: 860 – 1000 nm

Filter	Range (nm)	Exposure time (s)
g	400–550	300
r	560–710	1200
i	700–850	1800
z	850–1000	4000
Z_1	850–970	n/a
Z_2	850–920	n/a
Y	970–1020	n/a

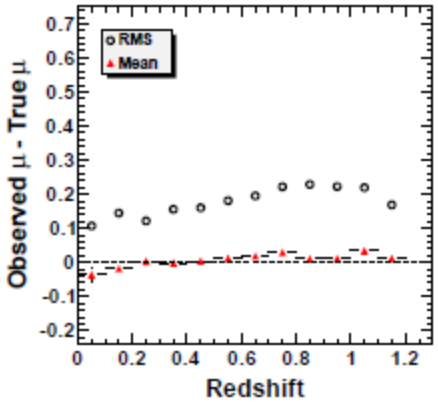
Deep; Wide = Deep/3

Number of SNe and Selection Efficiency

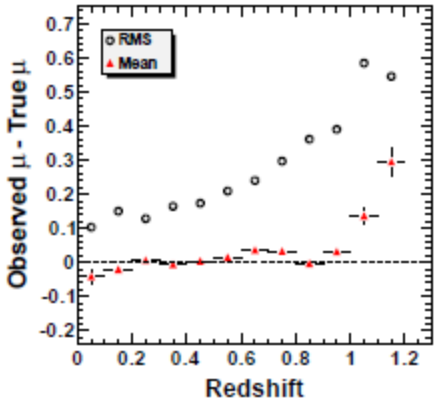




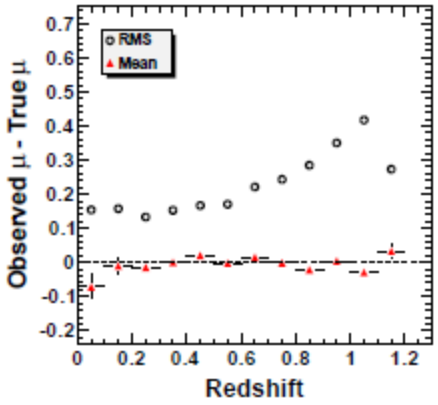
True Distance Recovery



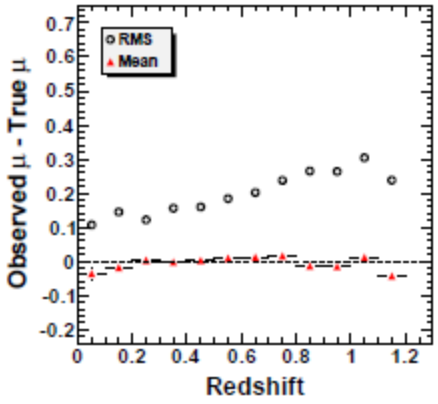
(a) MLCS2k2 fit for hybrid strategy with full priors.



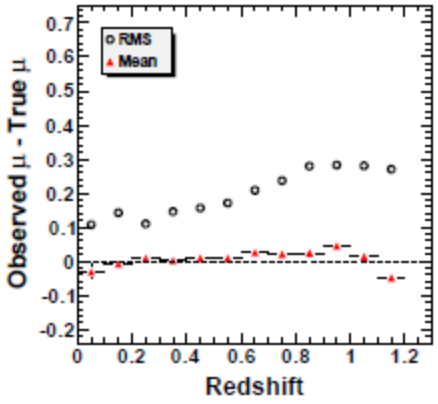
(b) MLCS2k2 fit for hybrid strategy with flat priors.



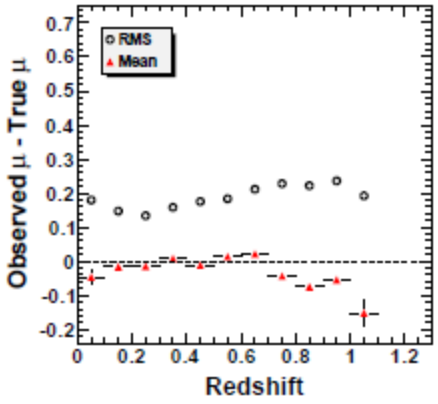
(c) SALT2 fit for hybrid strategy.



(d) MLCS2k2 fit for hybrid strategy with partial prior without efficiencies applied.

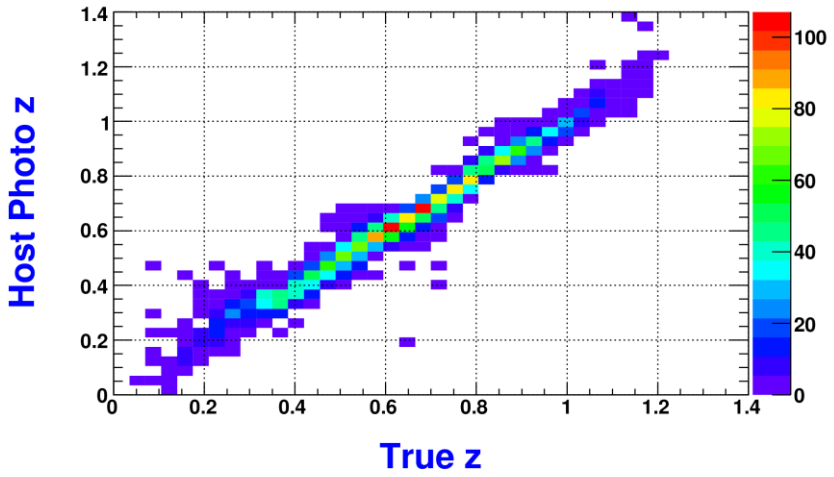


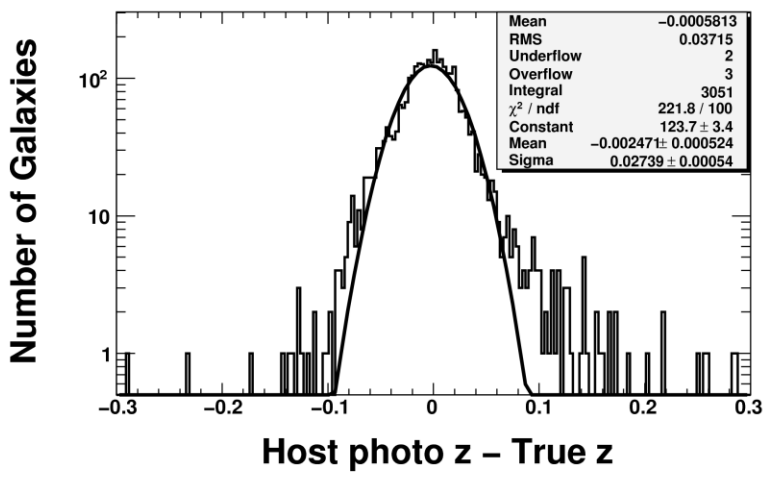
(e) MLCS2k2 fit for deep strategy with partial prior without efficiencies applied.

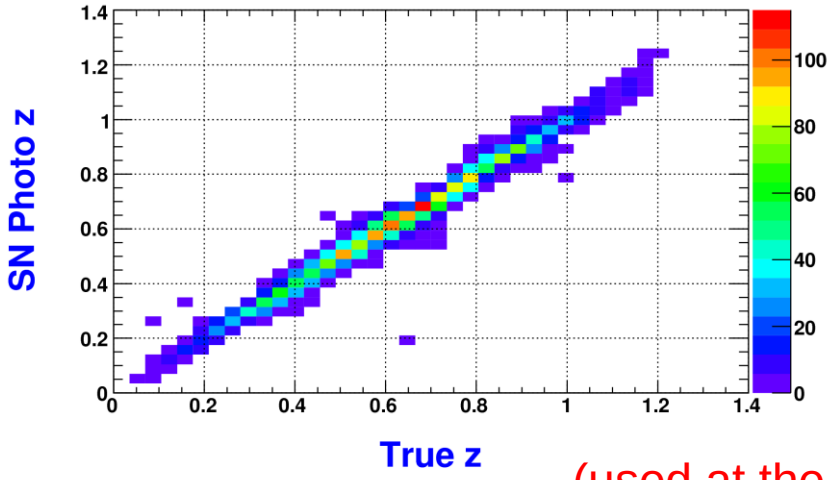


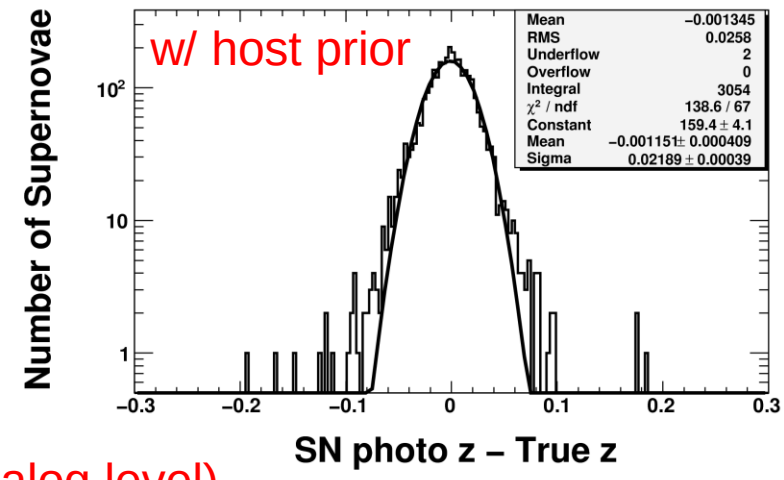
(f) MLCS2k2 fit for wide strategy with partial prior without efficiencies applied.

Photometric Redshifts



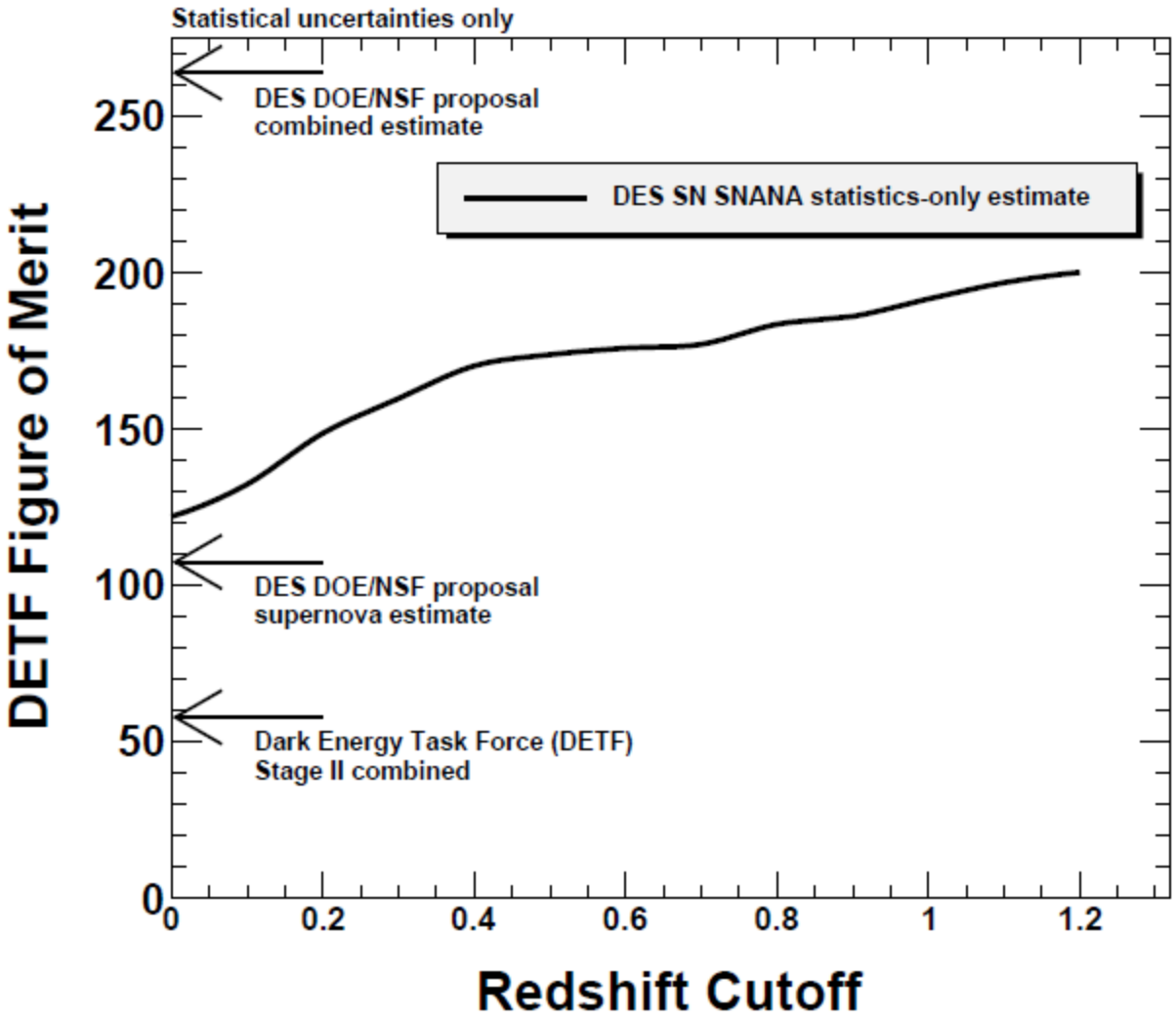






(used at the catalog level)

Updated Spectroscopic z Cutoff Plot



Input Core Collapse SN Rate & Relative Fractions

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- Use $\alpha(1+z)^{\beta}$, with β=3.6 (same as SFR)
- Determining α
  - Use SNLS CC/Ia ratio of 4.5 for z<0.4
  - Gives $\alpha=6.8\times 10^{-5}$

Reference	Ib/c fraction
Li et al. (2007)	26.5 ± 5.4%
van den Bergh et al. (2005)	24.7 ± 2.6%
Smartt et al. (2009)	29.3 ± 4.7%
Prieto et al. (2008)	24.7 ± 4.9%
Leaman et al. (2009)	33.3 ± 4.3%
Cappellaro et al. (1999)	15-22%

Table 3: Various references for the relative fraction of type Ib/c supernovae.

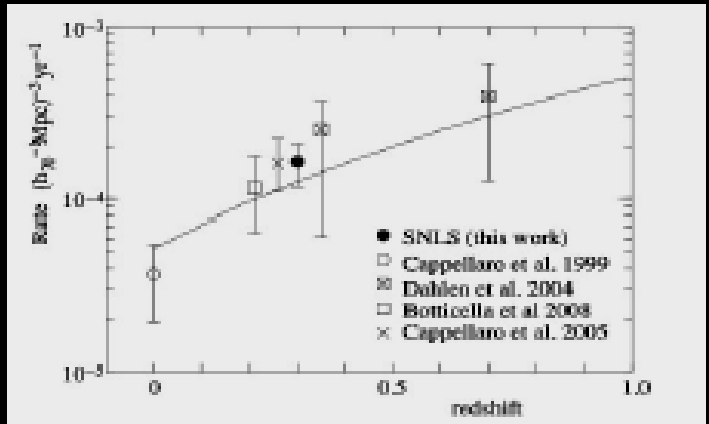
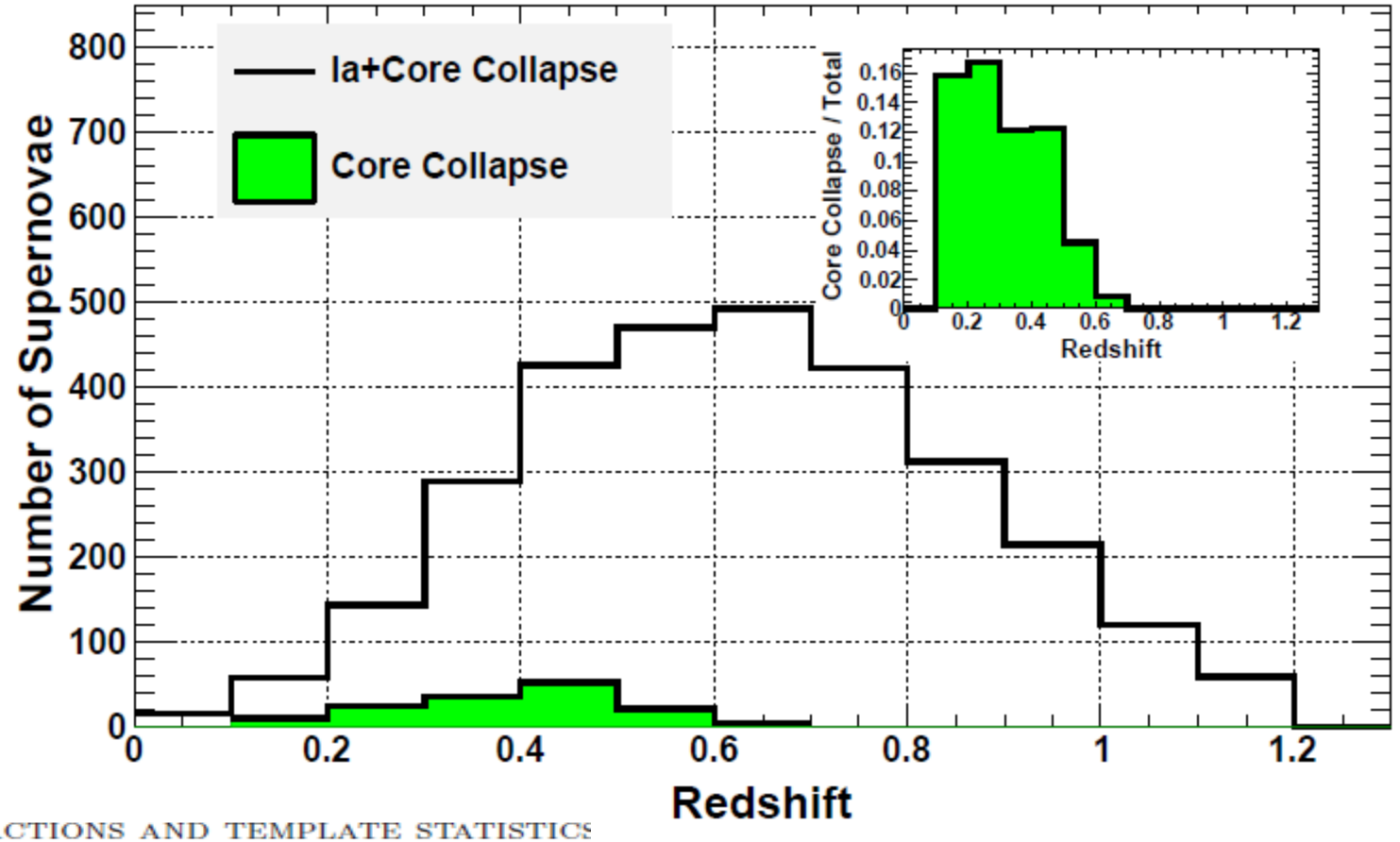


Fig. 13. The measured rate of SNcc as a function of redshift. The SNLS point includes a 15% correction for host absorption as described in the text. The error bars correspond to statistical and systematic uncertainties added in quadrature. The line is the best fit for rate$\propto (1+z)^{3.6}$, i.e. proportional to the SFR.

Forecasted Purity

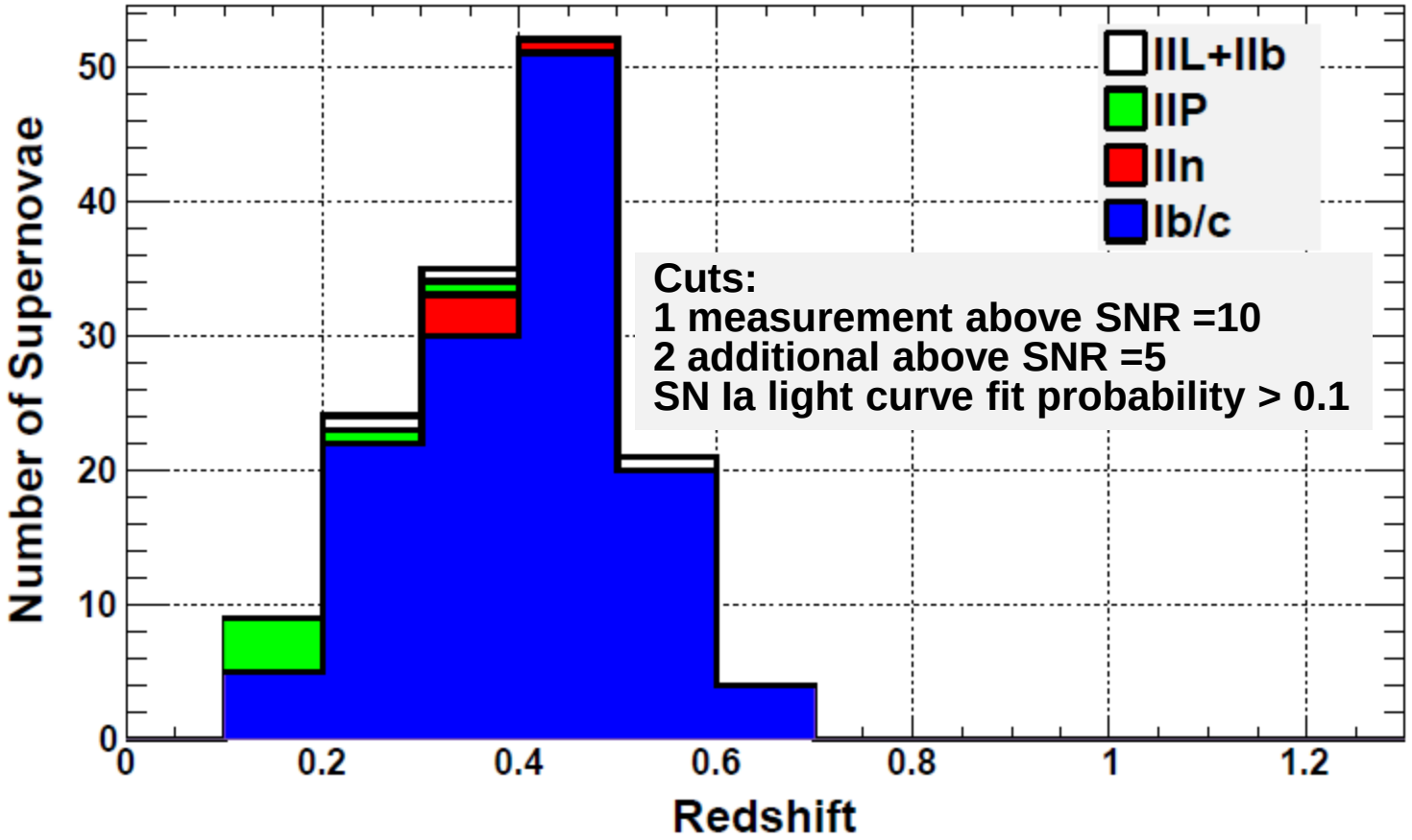


NON-IA SUBTYPE FRACTIONS AND TEMPLATE STATISTICS

Smartt et al.

non–Ia subtype	fraction	No. of measured templates	No. of composite templates
Ibc	0.29	16	1
II-P	0.59	23	1
II-L	0.08	0	1
IIn	0.04	2	1

Core-collapse Stacked Redshift Distributions



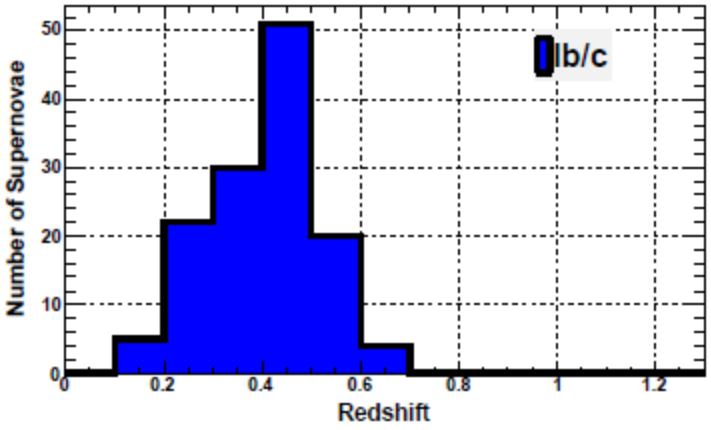
Total: 145 Ibc: 132 Iin: 4 IIP: 6 IIL: 3

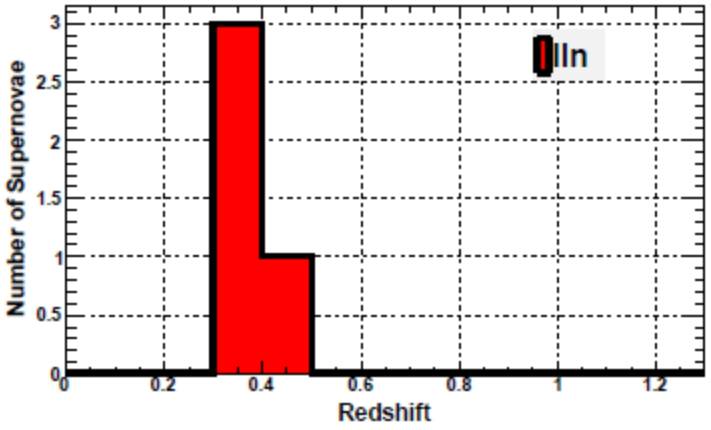
α up 1 sigma $\Rightarrow$ Total: 194

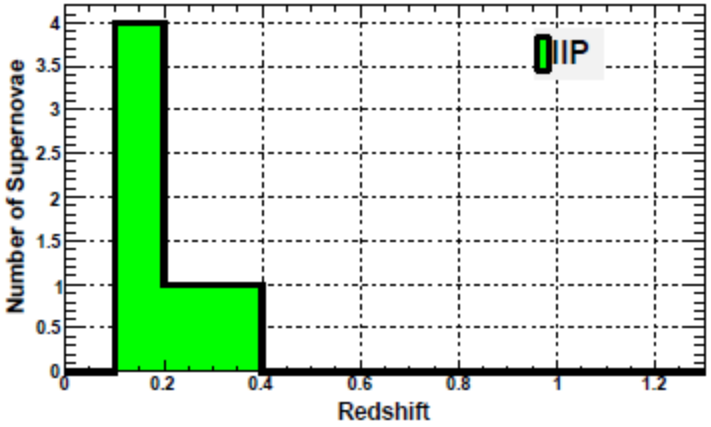
Ibc fraction up $1\sigma \Rightarrow$ Total: 178

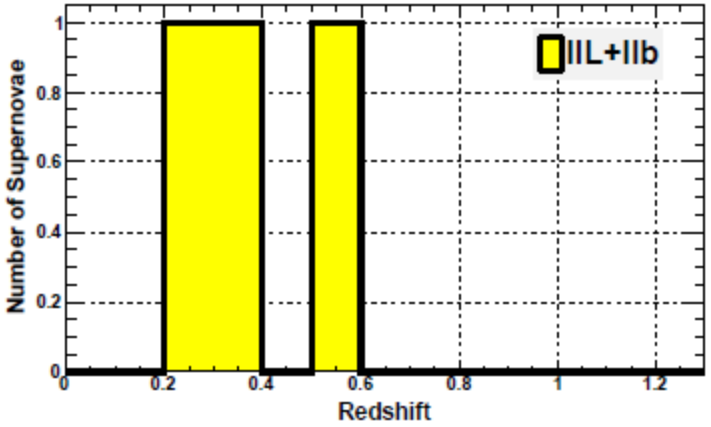
Leads to 0.02 change in DE equation of state parameter

Core-collapse Individual Redshift Distributions





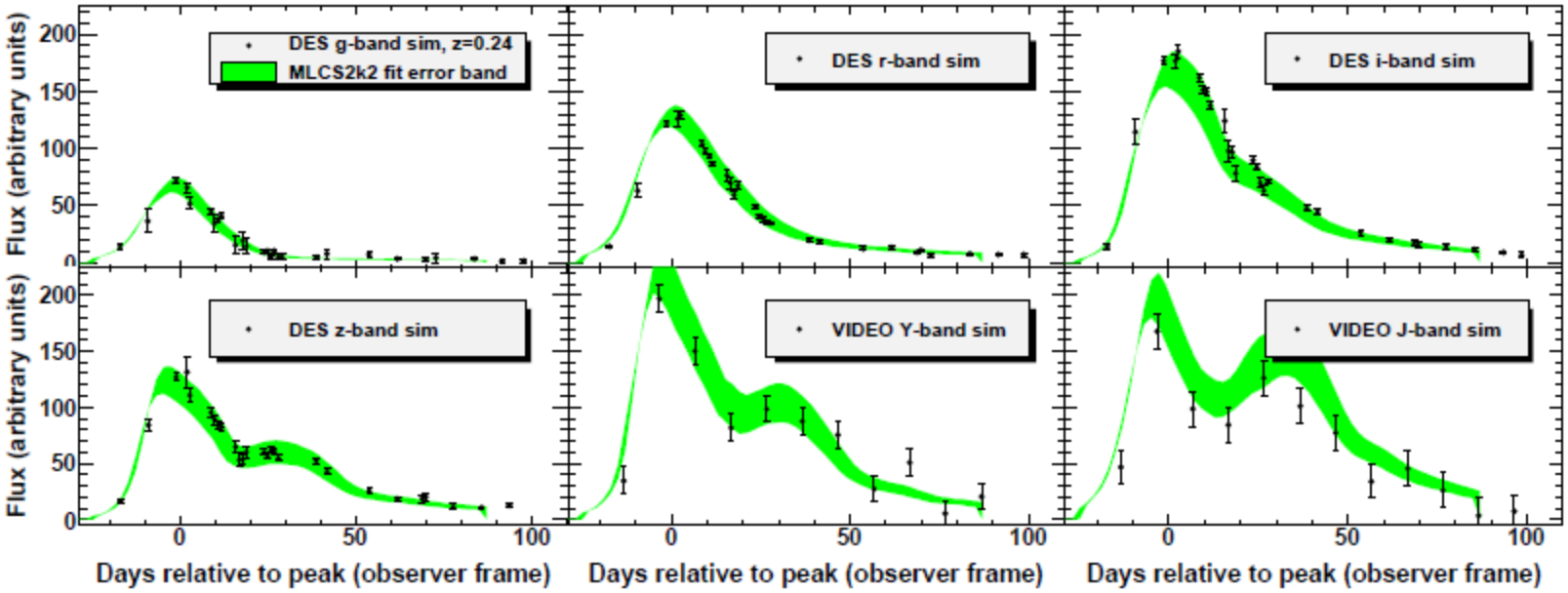




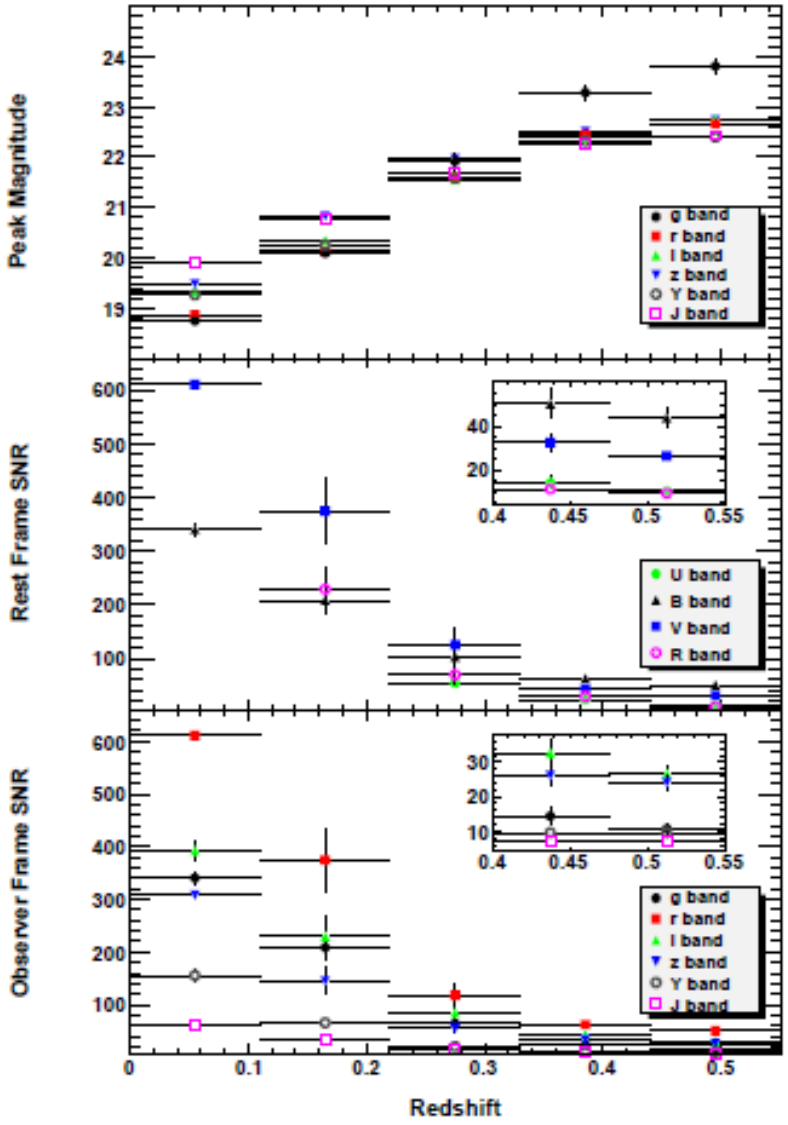
SNANA IR Simulations

- New IR model for SNANA: mlcs2k2.IR paper
  - UBVRIYJHK filters
  - uses UBVRI data from mlcs2k2.v006b
  - vectors by J. Marriner, currently -10 to +71 days only
  - uses new 9-filter genmag_mlcs.c routine
  - UBVRI works as mlcs2k2.v006b if YJHK templates do not exist
- NB: A_V-prior dominates YJHK fits b/c sim has no lever arm on color
- IR sims & DES-SN sim paper
  - introduce VIDEO connection & show SNANA IR capability
  - branch full IR study off in separate paper
  - IR meaty subject (e.g., Alex Kim's preliminary IR SNR results)
  - allows for our VIDEO external collaborators to be co-authors

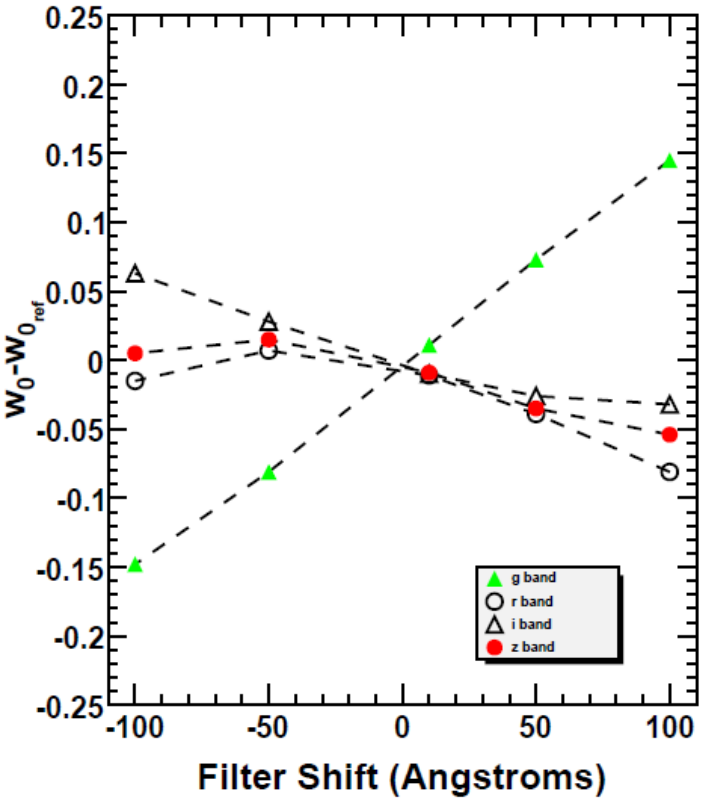
Example DES+ VIDEO SN Ia Light Curves

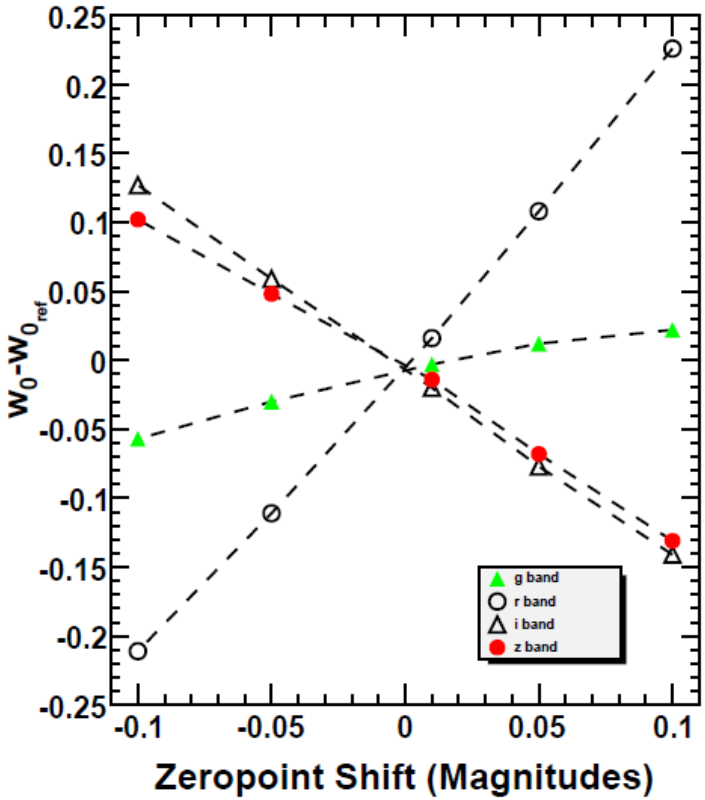


Example DES+VIDEO SN Ia Peak Mags & SNR



Systematic Studies





- Zeropoint shifts
  - 0.01 (DES spec) leads to 0.03 change in w
  - linear: 0.02 (too large) leads to 0.06 change in w
- Other systematics still under evaluation
  - mostly “community-wide”, e.g., dust, with many working to reduce
  - we can improve zeropoint systematic with PreCam

Summary & Conclusions

- DECam on track for delivery to CTIO in late 2011
- DES will compile a sample of ~3000 well-measured SNe to z~1
- Hybrid strategy of “deep” and “wide” fields currently favored
- Simulated DES photoz performance encouraging
- Core-collapse contamination under control prediction
- DES-SN Strategy simulation paper nearing submission
- Ongoing/Future work
  - further systematics studies
  - model spectroscopic follow-up strategy
  - follow-on DES+VIDEO IR SN paper